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Soil amendments by Organic and Inorganic Fertilizers for the Growth and Yield Performance of *ABELMOSCHUS ESCULENTUS* L. (MOENCH) (OKRA)

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ABSTRACT:
This study investigated the effects of soil amendments by organic and inorganic fertilizers for the growth and yield performance of *Abelmoschus esculentus* L. (Moench). Field trials were carried out at the field section of Bioresources Development Centre, Odi, in 2017 cropping season. The treatment consisted of sugarcane-bagasse+poultry-waste (SBPW) at 3:2, compost tea, NPK (15:15:15) and control without fertilizer arranged in a randomized complete block design and replicated three times. The NPK fertilizer and SBPW were applied 2 table spoonful per plant and compost tea was applied 100 mL per plant during vegetative growth of plant. Data were obtained for plant height, number of leaf, stem girth, leaf width, leaf length and fresh weight of fruit on ten (10) plants that were randomly sampled. SBPW, compost tea and NPK influenced the growth and yield performance of okra. NPK and SBPW at week 3 after 3WAP produced the highest plant height of 37.60 and 37.19 cm, respectively. Also, highest number of leaves and leaf width per plant was obtained in the application of SBPW having 14.00 and 30.76 respectively. The highest leaf length was evidenced in NPK application (31.06) and stem girth had the highest in compost tea application (6.18). The control, without fertilizer, was significantly the lowest in the growth parameters compared with other treatments but had the highest number of fruit set ($p<0.05$). The highest average fruit fresh weight was obtained in SBPW application. Hence, the organic fertilizers, especially SBPW as amendment is therefore recommended on both enriched and malnourished soil.

Keywords: Amendments, fertilizers, growth, compost tea, Sugarcane-bagasse+poultry waste

INTRODUCTION

Soil fertility is diminishing gradually due to soil erosions, loss of nutrient, accumulation of salts and other toxic elements, water logging and unbalanced nutrient compensation. These soils are poor with respect to their physico-bio-chemical properties as well as their nutritional status. The low yield of crops has been attributed to poor soil fertility and deficiency in important mineral nutrients [1]. Within this context, applying organic materials to soil not only generates a better nutritional state, but furthermore, positively influences the chemical and physical characteristics of the soil, which ultimately generate high production with minor environmental impact [2]. Farming regions where heavy chemical application is emphasized, usually lead to adverse environmental, agricultural and health consequences. Many efforts are being exercised to combat the adverse consequences of chemical farming [3]. Bio-fertilizer, organic manuring and bio-control have emerged as a promising component of integrating nutrient supply system in

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agriculture. Organic farming production system aims at promoting and enhancing agro-ecosystem health, biodiversity, biological cycles and soil biological activities. Even though, both chemical fertilizers and organic materials have a potential role in crop growth and development [4], the chemical fertilizers have become a scarce commodity and even when available; it is beyond the reach of the poor resource farmers due to high costs [5]. The application of organic manure had been found to have higher comparative economic advantage over the use of inorganic fertilizer [6]. It is on this ground, the use of organic fertilizers in comparison with chemical fertilizer was employed in this study to assess their impact on the growth and yield performance of Okra.

Okra (*Abelmoschus esculentus* L. Moench) is an annual, herbaceous flowering plant in the Malvaceae family that originated from tropical and subtropical Africa and is natural to the West Africa [7]. It is an important vegetable crop grown for its immature pods that can be consumed as a fried or boiled vegetable or may be added to salads, soups and stews [8], in countries like Sudan, Egypt and Nigeria and in other tropical areas including Asia central and South America. The fruits can be conserved by drying or pickling, the roasted seed is considered as coffee substitute; the leaves, flower buds, flowers and calyces can be eaten cooked as greens [9], while the roots and stems are used for preparing "gur" or the brown sugar [10]. Mature Okra seeds are a good source of vitamins, minerals, calories and amino acid that could be compared favorably with those in poultry eggs and soybean [11, 12] and also as a source of seed oil [13]. In Nigeria, okra is grown in both wet and dry season but attract a larger profit in the dry season when the demand is often in excess with limited supplies [14].

Okra cultivation requires nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na) and Sulphur (S) for fertility maintenance and crop production. These nutrients are specific in function and must be supplied to plants at the right time and at the right quantity. Lack of sufficient amounts of these nutrients result in poor performance of the okra with growth been affected resulting to low yield [10]. In developing countries like Nigeria, the population growth rate is so high that improved technologies including rational use of fertilizers must be employed to meet the food requirement of the people [15].

Organic fertilizers are very essential for proper development of plants as they offer rapid growth with superior quality by containing some nutrient that's necessary for better development. It has been reported that application of vermi-compost and poultry manure subsequently increases yield attributing characters and yield of okra [16]. It was also reported that poultry manure seems to promote higher growth and yield of okra [17]. Another study conducted by [18], reported that integrated nutrient (inorganic fertilizer + poultry manure) applications increases yield of tomato and okra.

Improving soil fertility through the application of fertilizers is an essential factor enabling the world to feed the billions of people that are added to its population [19]. Declining soil fertility is a major production constraint in Africa, especially in Nigeria, and it is becoming increasingly critical to secure sustainable soil productivity [20, 21].Thus, there is a need for cultivation of okra with

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increased yield and quality, which this present study is aimed at, and that is to evaluate the effects of the following fertilizer application; organic (sugarcane bagasse+poultry waste (SBPW), Compost tea) and inorganic (N:P:K 15:15:15) fertilizer as soil amendments on the growth and yield of Okra (*Abelmoschus esculentus*). The specific objectives include

1. To evaluate the growth and yield performances of okra in the different application of the types of fertilizers on a rich-nutrient soil
2. To identify the best organic fertilizer which enhances both growth and yield performance of okra on a rich-nutrient soil
3. To ascertain the effects of excessive naturally enriched-soil with soil amendments on the growth and yield performance of Okra

MATERIALS AND METHODS

Study site

The experiment was conducted at the field section of Bioresources Development Centre (BIODEC), Odi, between April and June, 2017. The area carved out for the experiment was an abandoned site with logs (from different source e.g. palm tree stem) to decompose for two years. The remains on the site after the two years were cleared properly before use.

Odi is situated in Bayelsa state, Nigeria, located about 23 kilometers from the capital city of Yenagoa. Bayelsa state is geographically located within latitude 4Â^{0}15´ North and latitude 5Â^{0}23´ South. It is also within longitude 5Â^{0}22´ West and 6Â^{0}45´ East. The state is bounded by Delta state on the north, Rivers state on the east and the Atlantic Ocean on the western and southern parts. Rainfall varies in quantity from one area to another. The state experiences equatorial type of climate in the southern and tropical rain towards the northern parts. The mean monthly temperature is in the range of 25^{0}C to 31^{0}C. The mean annual temperature is uniform for the entire state. The hottest months are December to April. The difference between the wet and dry season on temperature is about 2^{0}C at the most. Relative humidity is high in the state through the year and decreases slightly in the dry season. The soil of the experimental region before and after abandonment was loamy-clay with pH 6.20 and 7.88 (Table 1).

Soil sampling and preparations

Pre-planting sampling was carried out on the experimental field to determine the inherent soil characteristics before treatment incorporation. Soil samples were collected at the depth of 0-15cm at various point of the field and bulked together for laboratory analysis. Samples were air -dried, gently crushed with a wooden roller and passed through sieves of 2 mm sizes for Total Dissolved solids (TDS), conductivity, phosphate, magnesium and other determinations respectively. Standard methods of physical and chemical analyses for soils were used to analyze these parameters.

Organic fertilizers preparations

Samples of the organic fertilizers were produced in Bioresources Development Centre, Odi, Bayelsa state and analyzed for Total Dissolved solids (TDS), conductivity, phosphate, magnesium and other determinations respectively.

Sugarcane bagasse+poultry waste

This was prepared in the ratio of 3:2 (Sugarcane bagasse:poultry waste). The bagasse was completely dried and carbonized

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by burning at a temperature of about 1000°C which was subjected to pyrolysis for complete burning. Sugarcane molasses was added to it which is termed “quenching”, to increase its ability to retain water and host more microorganisms that will aid the decomposition process. The poultry waste was then added to increase the nutrient level (especially the nitrate and phosphate). The mixture was left to dry for 5 days and was milled to powdered form.

Compost tea

Plant residues from different sources were piled up in a constructed building, fastened to the building was a tap that run from the inside to the outside where the compost tea can be collected. Vents were also created up and bottom for the passage of air to activate the beneficial fungi and bacteria in the compost. Water was added to the plant residues for brewing.

Experimental design and Treatment application

The experiment was laid out in a Randomized Complete Block Design (RCBD). The total number of plots was four consisting of three beds each with 10 plants. Overall of the plants including the three beds were 120 plants with each bed consisted of 30 plants. The plot dimension was 2m x 5m each with 0.5 m spacing between beds and 1 m apart in each block of rows for easy movement during cultural operations. The seeds were planted at a spacing of 0.5m x 0.5m and two seeds were put per hole and thinned to one seedling per stand after their germination. The variety of okra seeds used was dwarf local and the viability test was conducted prior to planting. Four treatments and three replicates were applied: T1 (untreated-neither inorganic nor organic fertilizers), T2 (SBPW), T3 (Compost Tea), T4 (N: P: K fertilizer). Raised seed beds were well prepared by ploughing and harrowing. The organic fertilizers were applied and incorporated directly in the hole and mixed with soil based on treatments two weeks before sowing, while NPK fertilizer was applied as a single dose two weeks after emergence by the ring method of application. The NPK fertilizer and SBPW were applied 2 table spoonful per plant and compost tea was applied 100 mL per plant during vegetative growth of plant.

Data Collection and Analysis

Plant height, number of leaves, leaf width, and leaf length and stem girth (diameter) per plant were measured by using a measuring tape. Random samples of ten plants per plot were selected and tagged for data collection. The unit used for measurement is centimeter (cm). This was accomplished by manual observation where the number of leaves per plant was counted. These were collected on weekly basis after 3 weeks of planting. Yield parameters included, number of fruits per plant, fruit length, fruit girth (diameter) and fresh fruit yield (g). Results were analyzed using the Analysis of Variance (ANOVA) by means of Statistical Analysis System (SAS, 2006). The Duncan’s Multiple Range Test (DMRT) was used to separate the means of treatment.

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Table 1a. Characteristics of soil sample before abandonment [28]

Parameter	Soil before abandonment
Total Dissolved Solids ,TDS (g/kg)	0.022
pH	6.20
Conductivity (µs/cm)	40
Chloride (g/kg)	0.006
Salinity (g/kg)	0.0099
Phosphate (mg/kg)	0.20
Nitrate (mg/kg)	0.70
Temperature (^oC)	26.70
Magnesium, Mg (g/kg)	0.679
Calcium, Ca (g/kg)	0.496
Iron, Fe (g/kg)	5.521
Manganese, Mn (g/kg)	0.113

Table 1b. Characteristics of Soil sample and organic amendments

Parameter	Soil after abandonment	SBPW	Compost tea
Total Dissolved Solids ,TDS (g/kg)	0.147	0.327	0.885
pH	7.88	8.43	6.0
Conductivity (µs/cm)	267	508.0	1,770
Chloride (g/kg)	0.0369	0.080	0.190
Salinity (g/kg)	0.0609	0.135	0.313
Phosphate (mg/kg)	0.79	1.11	1.70
Nitrate (mg/kg)	2.00	2.50	2.00
Temperature (^oC)	27.00	26.90	26.70
Magnesium, Mg (g/kg)	1.088	1.108	0.062
Calcium, Ca (g/kg)	5.428	4.805	0.044
Iron, Fe (g/kg)	6.533	3.053	0.048
Manganese, Mn (g/kg)	0.174	0.153	0.00224

SBPW: Sugarcane bagasse+poultry waste

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Table 2a. Measurement of growth parameters of Okra at week 1 after 3 WAP, n=10

Treatments	Parameters				
	Plant height (cm)	Number of leaves	Leaf width (cm)	Leaf length (cm)	Stem girth (cm)
No fertilizer	12.68±2.09^{bc}	6.7±1.64^{b}	12.88±2.54^{bc}	18.91±4.57^{b}	1.78±0.49^{c}
SBPW	16.59±5.81^{a}	8.1±1.85^{a}	14.89±3.68^{ab}	20.99±5.03^{b}	2.1±0.69^{ab}
Compost tea	15.29±3.08^{ab}	8.7±1.49^{a}	14.64±3.21^{ab}	22.60±5.51^{ab}	2.48±0.55^{a}
N: P: K fertilizer	14.19±2.58^{ab}	8.2±0.79^{a}	16.11±2.05^{a}	25.60±3.47^{a}	2.15±0.36^{ab}

* Results are reported as Mean±SD; SBPW: Sugarcane bagasse+poultry waste
*Values within a column having different alphabet superscripts are statistically significant ($p<0.05$) according to Duncan's multiple range tests analysis

Table 2b. Measurement of growth parameters of Okra at week 2 after 3 WAP, n=10

Treatments	Parameters				
	Plant height (cm)	Number of leaves	Leaf width (cm)	Leaf length (cm)	Stem girth (cm)
No fertilizer	15.09±3.35^{b}	8.80±2.39^{b}	22.36±5.15^{b}	19.56±3.72^{c}	3.19±0.92^{d}
SBPW	21.99±3.40^{a}	10.70±1.83^{ab}	25.31±3.35^{ab}	22.88±2.71^{b}	3.85±0.37^{bc}
Compost tea	20.13±3.59^{a}	11.70±1.77^{a}	26.39±4.46^{a}	23.22±4.57^{b}	4.12±0.73^{ab}
N: P: K fertilizer	20.27±2.50^{a}	11.20±2.62^{a}	26.28±2.79^{a}	26.61±3.17^{a}	4.48±0.47^{a}

* Results are reported as Mean±SD; SBPW: Sugarcane bagasse+poultry waste
*Values within a column having different alphabet superscripts are statistically significant ($p<0.05$) according to Duncan's multiple range tests analysis

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Table 2c. Measurement of growth parameters of Okra at week 3 after 3 WAP, n=10

Treatments	Parameters				
	Plant height (cm)	Number of leaves	Leaf width (cm)	Leaf length (cm)	Stem girth (cm)
No fertilizer	21.13±4.28^{c}	10.00±2.45^{b}	24.14±5.37^{bc}	24.07±5.37^{b}	4.02±1.50^{c}
SBPW	37.19±4.14^{a}	14.00±2.45^{a}	30.76±4.92^{a}	26.71±3.88^{ab}	4.77±0.87^{bc}
Compost tea	30.11±8.06^{b}	13.78±2.68^{a}	28.10±5.21^{ab}	24.94±8.16^{b}	6.18±0.77^{a}
N: P: K fertilizer	37.60±4.11^{a}	12.90±2.81^{a}	30.02±3.63^{a}	31.06±4.60^{a}	5.72±1.14^{ab}

* Results are reported as Mean±SD; SBPW: Sugarcane bagasse+poultry waste
*Values within a column having different alphabet superscripts are statistically significant (p<0.05) according to Duncan's multiple range tests analysis

Table 3. Measurement of yield parameters of Okra; N=10

Treatments	Parameters			
	Number of fruit sett	Fruit length (cm)	Fruit diameter (cm)	Average Fresh weight (g)
No fertilizer	18.00±1.27^{a}	7.56±1.24^{c}	9.54±1.04^{c}	6.60^{b}
SBPW	11.50±1.27^{b}	12.44±1.23^{a}	11.48±0.78^{a}	8.24^{a}
Compost tea	10.40±3.20^{b}	12.76±1.02^{a}	11.73±1.21^{a}	7.45^{a}
N: P: K fertilizer	12.10±3.60^{b}	10.19±1.27^{b}	9.91±1.06^{b}	7.20^{a}

* Results are reported as Mean±SD; SBPW: Sugarcane bagasse+poultry waste
*Values within a column having different alphabet superscripts are statistically significant (p<0.05) according to Duncan's multiple range tests analysis

RESULTS AND DISCUSSION

Soil and organic manure properties

The texture of the soil used for the trial was loamy clay with low alkaline in pH and slightly high in macronutrients and micronutrients (Table 1b). These were different from the typical characteristics of the soil within the area as indicated in table 1a as

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"before abandonment"; this was because of the decomposed logs on the experimental site. The soil after abandonment was higher in conductivity; hence, according to [22], conductivity can be used as a measure of the potential nutrient level of a water source and therefore, a measure of Total Dissolved Solids (TDS). The salinity level was higher in the soil after abandonment. The available Nitrogen in the experimental soil after abandonment in the form of nitrate ion was high compared to "before abandonment". Similarly, the available phosphorus in the form of phosphate ion was also higher compared to "before abandonment". Nitrogen has been identified as the major limiting nutrient for plants followed closely by phosphorus [23, 24]. Other macronutrients which include calcium and magnesium present in the soil after abandonment were relatively higher. Similarly, the micronutrients which include Iron, Manganese and Chloride were relatively higher (table 1b). Each of the nutrients is needed in different amounts and carries specific functions in the plant. Depending on the amount that is available for plant uptake, these nutrients influence crop yields and quality [25]. Some crop quality attributes influenced by the nutrients include; sugar and protein content, seed size, kernel size, fruit colour, flavour, vitamin levels and grain hardness [26]. The nutrient contents of the organic fertilizers are shown in Table 1b. The nitrate content was higher in SBPW than in compost tea while the phosphate content in compost tea was higher than in SBPW. Similarly, the other nutrients including magnesium, calcium, iron and manganese were higher in SBPW than in compost tea with the exception of chloride. Compost tea was higher in conductivity than in SBPW which is a measure of total dissolved solids. The pH of SBPW was slightly alkaline and compost tea was slightly acidic. The level of salinity in compost tea was higher than in SBPW (table 1b). Plants typically have some tolerance to salinity, and salinity can increase without affecting yield or other plant attributes. However, at a critical threshold value, further increases in salinity begin to affect yield and plant growth [27].

Effect of soil amendments on growth parameters of okra

The results indicated that the different soil amendments had high significant ($p<0.05$) effect on the growth of Okra (*Abelmoschus esculentus*) as shown in Table 2a-c.

At week 3 after 3 WAP, the application of NPK and SBPW had the highest significant ($p<0.05$) effect on the plant height followed by compost tea while the lowest plant height was obtained from the control (Table 2c). In week 2 and 1, as regards the treatments, there was no significant difference between NPK, SBPW and compost tea (Table 2a & b). The effect on the plant height at week 3 might be the high nitrate content present in NPK and SBPW treatment compared to compost tea with lower content as it function in promoting rapid growth [29]. The number of leaves was significantly ($p<0.05$) increased when SBPW, compost tea and NPK was applied while the least number of leaves was produced in the control in week 3 after 3WAP (Table 2c). In week 2, there was no significant difference between SBPW and the control (Table 2b). Similarly, in week 1, there was no significant difference among the three amendments/treatments (Table 2a). This shows that compost tea were readily available in the best form for easy absorption by the plant roots, hence there was a boost in the vegetative growth affecting the number of leaves of the plant and this was in accordance

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with [30] who reported that the increase in number of leaves per plant with organic fertilizer application stressed its importance during the vegetative growth of crop plants.

The leaf width of the Okra plants was significantly ($p<0.05$) increased in SBPW, NPK and then followed by compost tea while the control had the smallest width. There was no significant difference between compost tea and control at week 3 (Table 2c). Similarly, there was no significant difference between control and SBPW applications in week 2 (Table 2b). In week 1, there was no significant difference among SBPW, compost tea and control (Table 2a). This was in agreement with [31] who reported that the application of poultry droppings alone gave plants the greatest morphological growth in relation to leaf width, not to talk of addition of sugarcane bagasse.

The leaf length was significantly ($p<0.05$) higher in NPK and SBPW while the control had the smallest length but no significant difference among SBPW, compost tea and control at week 3 (Table 2c). In week 2, there was no significant difference between SBPW and compost tea, with NPK producing the highest length and control was the least (Table 2b). Similarly, there was no significant ($p<0.05$) difference between NPK and compost tea in week 1 (Table 2a). This was in accord with [32] who reported that the fertilizer NPK significantly increase growth parameters of okra obtained vis-à-vis the leaf length.

The stem girth of Okra plants was significantly ($p<0.05$) increased when compost tea was applied followed by NPK with no significant difference between them and control had the least girth in week 3 (Table 2c). In week 2, there was significant ($p<0.05$) increment in NPK and compost tea followed by SBPW and the control been the least (Table 2b). Similarly, in week 1, there was no significant difference among compost tea, NPK and SBPW (Table 2a). The effect of the significant increment in the stem girth of okra at week 3 might be the higher phosphate content in the compost tea compared to SBPW as shown in table 1b. Within the stem resides the cambium where cell division takes place for a growing plant. Stems cannot widen without phosphate ion that plays an important role in cell division which leads to the increase in width of stem. Furthermore, it might be its degree of absorptiveness which according to [33, 24, 34, 35] reported that the more readily nutrients are available to a crop, the higher the performance of the crop and vice versa.

There was only a moderate yellowing of leaves in the application of SBPW and necrosis of leaf margins in the application of compost tea and NPK at week 3 after 3WAP. This is symptomatic to iron and chloride [36], which might be as a result of their slight accumulation in the soil. However, unlike other micro-nutrients, chloride is not toxic when it accumulates to high levels in plants. The symptoms of chloride toxicity (higher concentrations) are associated with the osmotic effect of saline soils. One of the most important factors affecting the uptake of nutrient elements by plants is the pH of the nutrient solutions and however, the pH (8.93 and 6.0)of the organic fertilizers were within the range of absorptiveness of nutrient elements by okra plant. Chloride toxicity is also associated with the activity of the nitrate reductase as nitrate and chloride has similar ionic properties and absorption mechanisms. When chloride uptake rises to the toxic level, it is easily converted to toxic compounds (like

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hypochlorites), before it can be detoxified with the nitrate reductase [37, 38].

Effect of soil amendments on yield parameters of okra

The results indicated that the different soil amendments had high significant ($p<0.05$) effect on the yield performance of Okra (*Abelmoschus esculentus*) as shown in Table 3.

Plots with the untreated (control) significantly ($p<0.05$) produced the highest number of fruits per plant. There was no significant difference among SBPW, compost tea and NPK application. This might be as result of excess accumulation of some of the macro and micronutrients in the other soil amendments groups. This might also be as a result of nutrient interactions where they act as antagonist where an increase in one nutrient reduces uptake and function of the other and eventually reducing yield. For instance, the rate of Mg uptake can be depressed by Ca and vice versa [39]. This is attributed to the competitiveness of Ca with Mg whereby the root plasma membrane binding sites have the higher affinity to Ca than to Mg [40]; albeit, application of compost tea and SBPW significantly produced longer fruits than NPK. Shorter fruit length was observed in the control treatment. Okra fruit diameter was similarly highest in compost tea, SBPW and NPK with no significant difference and shorter diameter produced in the control treatment. Application of compost tea, SBPW and NPK fertilizers also had similar fresh fruit weight which was significantly different from the control treatment (Table 3). This could be attributed to the significant performance of the morphological (growth) parameters when treated with compost tea, SBPW and NPK fertilizers as this could affect the fruit quality. Furthermore, the positive response of the fruit yield to the different applications could be due to the synthesis of more assimilate that played significant role in flowering and increment of fruit weight [41]. According to [42], application of sugarcane bagasse improved the physical condition of soil by reducing bulk density and enhanced macro-spore for a better root growth, and ultimate enhanced the cane yield.

CONCLUSION

The organic fertilizers (SBPW and compost tea) are safe and as a result, it is effective and can easily be adopted by farmers. They not only increased macronutrient contents, but also enhanced micronutrient contents of the plant organs. The study assumes that these soil amendments play a major role in plant nutrient uptake and growth parameters in plants and have a great potential to increase the yield performance, growth and mineral contents of okra plant which can be a substitute for chemical fertilizers that is detrimental to the ecosystem. They also have the potential to benefit such farmers in many ways and hence, its importance should be recognized by farmers as well as researchers. Therefore, they, especially SBPW, may be put to good use as natural fertilizer for vegetable production in sustainable and ecological agricultural systems.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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